Non-invasive attractor reconstruction analysis for early detection of deteriorations

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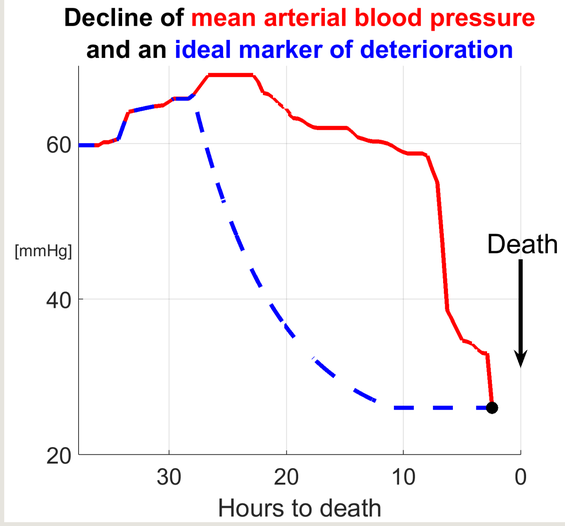
1. Early detection of deteriorations using attractor reconstruction

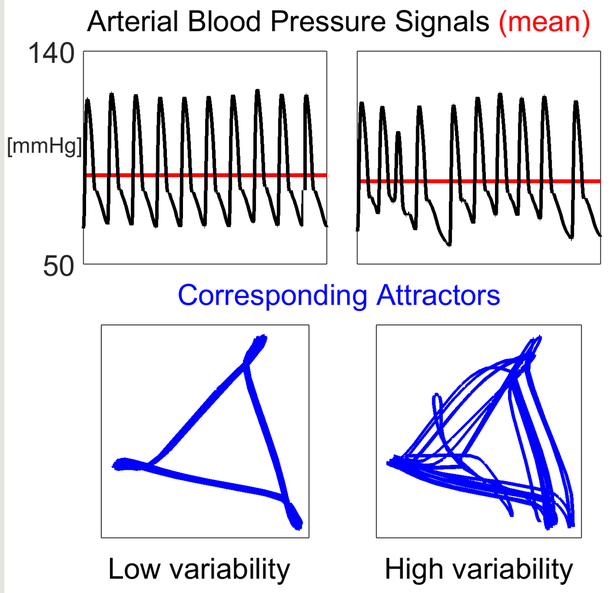
The importance of early detection of deteriorations

Clinical deteriorations of hospital patients leading to events such as cardiac arrests, critical illnesses, and deaths must be recognised early to maintain patient safety.

Deteriorations are commonly preceded by changes in cardiovascular state. However, routinely measured cardiovascular parameters such as blood pressure often provide only minimal advanced warning (see right).



Data: MIMIC II Clinical Database, with thanks to Marco Pimentel.



Attractor reconstruction as an early marker

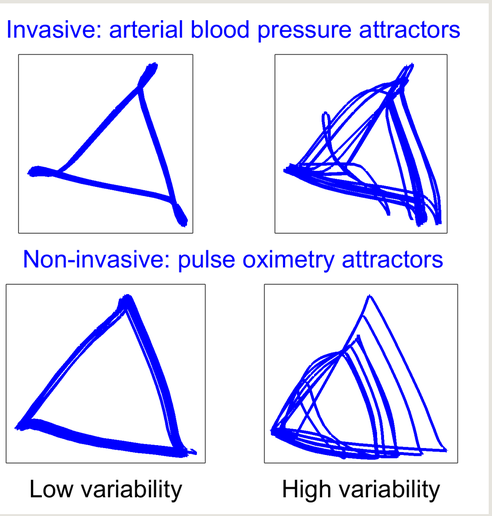
Changes in cardiovascular variability have been observed to occur earlier than changes in cardiovascular parameters.

Attractor reconstruction quantifies the variability of cardiovascular signals, so may provide improved markers of deterioration. It represents a signal as an attractor in 2D phase space (see left).

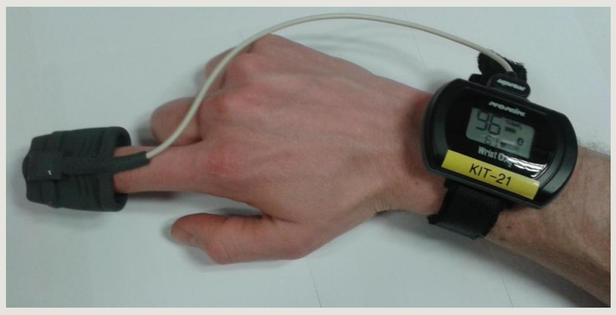
2. Proposed developments for clinical use

Non-invasive measurement

Attractor reconstruction has previously been applied to arterial blood pressure signals. These are only available in critical care via invasive measurement. In contrast, pulse oximetry signals are measured every 4-12 hours in hospital patients. We hypothesised that cardiovascular variability could be measured using this non-invasive signal instead. If so, attractor reconstruction could be used with all hospital patients, rather than just those in critical care.

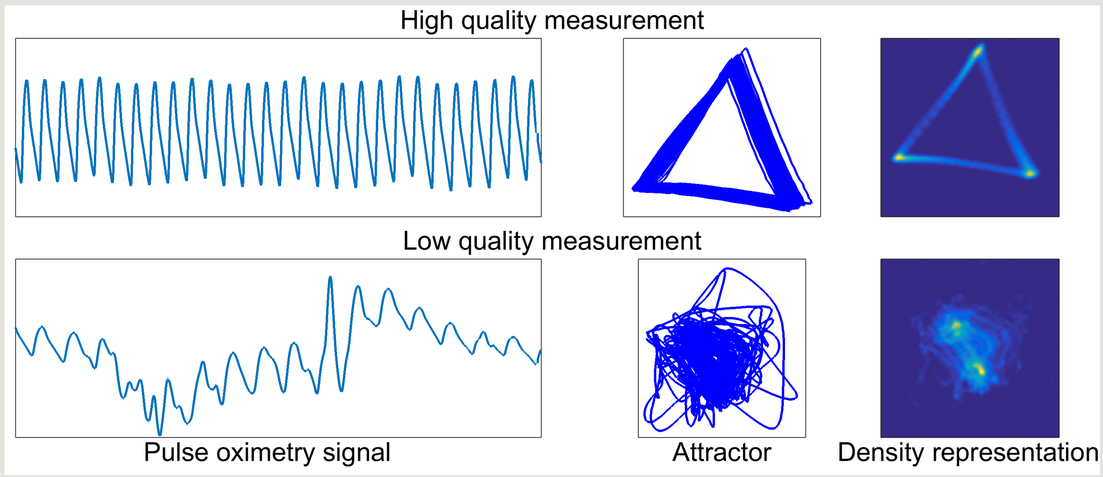


Pulse oximetry measures arterial blood volume, so is closely related to arterial blood pressure (left). It can be easily measured as shown below.



Elimination of low quality measurements

If attractor reconstruction is to be used in hospital then it must be robust to artifact due to factors such as movement or loosening of sensor attachments. The Attractor Quality Index was proposed to discriminate between high and low quality attractor reconstruction. As shown below, high quality measurements result in a high density of points at the three vertices of a triangular attractor. The attractor quality index quantifies the presence or absence of these high density regions to determine the quality of attractor reconstruction.

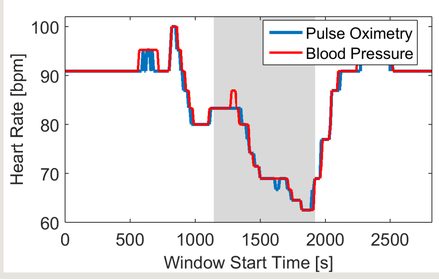


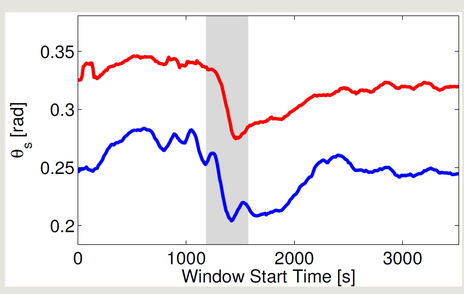
3. Clinical evaluation of developments

Dataset Arterial blood pressure and pulse oximetry signals acquired from six critically ill patients were used to compare attractor reconstruction of the signals. Recordings were obtained before, during and after a change in cardiovascular state caused by increased vasopressor dosage (shown by grey shading) [1].

Agreement between signals' heart rates

Heart rates (right) derived from arterial blood pressure and pulse oximetry signals using attractor reconstruction agreed very closely.



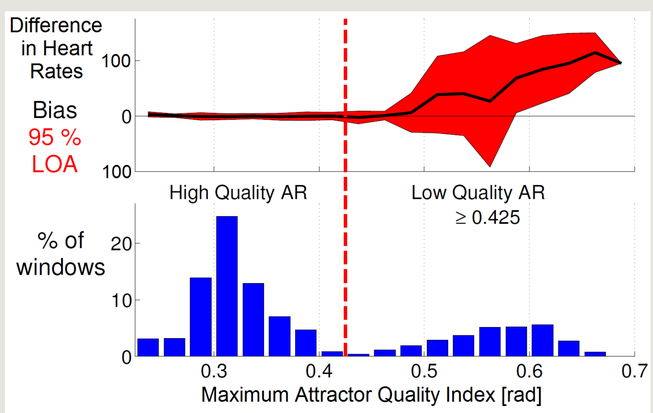


Similar trends in variability measures

Measures of cardiovascular variability (left) trended similarly between the two signals, although absolute values did not agree..

Identification of low quality measurements

As shown below, there was high agreement between the heart rates derived from each signal when the Attractor Quality Index was below a threshold value (to the left of the red dashed line). Otherwise, there was poor agreement, demonstrating the ability of the Attractor Quality Index to discriminate between high and low quality measurements.



References

[1] J. Smith *et al.*, "Effects of norepinephrine-driven change in arterial blood pressure on four different continuous cardiac output systems in critically ill patients," *Int Care Med.*, vol. 37 S1, p. S280, 2011.

The paper accompanying this poster is:

Charlton, P. H. et al., "Measurement of cardiovascular state using attractor reconstruction analysis,"Conf Proc EUSIPCO., 2015. [in press]

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